The University of Minnesota

AGRICULTURAL EXTENSION DIVISION

Special Bulletin No. 7

University Farm, St. Paul — March 1916

Published by the University of Minnesota, College of Agriculture, Extension Division, A. D. Wilson, Director, and distributed in furtherance of the purposes of the coöperative agricultural extension work provided for in the Act of Congress of May 8, 1914.

QUACK GRASS ERADICATION

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SUMMARY

Methods for preventing the spread of quack grass and for eradicating it are based on knowledge of its habits of growth.

Quack grass seed will grow even if the plant is cut before the seed is mature. In order to prevent quack grass from developing seeds to the point where they will germinate, crops in which it is growing should be cut not later than the last week in June.

Young quack grass plants, if attacked before they have formed underground stems, are as easily killed as plants of wheat or other grains of the same age.

Manure containing quack grass seed may be applied on plowed ground before preparing the soil for a cultivated crop. The seed will grow the same season and the young plants will be killed in the preparation of the seed bed and the cultivation of the crop if thoro work is done.

Digging by hand and removing from the field all portions of the plant, smothering with tar paper, or spraying with a solution of sodium arsenite is best for the complete eradication of quack grass on small spots.

All methods of eradication on large fields are based on thoro tillage.

The implements found on any well-equipped farm are all that are needed to eradicate quack grass.

The most effective bare-fallow method of eradication tried was plowing in July three or four inches deep, replowing not later than August 15 five or six inches deep, and again in November six or seven inches deep. The disk was used as needed between plowings to keep the quack grass from showing green above ground. The cost of the additional labor necessary for complete eradication under this system was $9.60 per acre. No crop was secured from the land that season.

Complete eradication of quack grass while following a system of crop rotation was found practical when more than the ordinary amount of tillage was given.

Tillage given now and then when nothing else needs immediate attention is largely lost effort in the eradication of quack grass. To be effective there must be a well-planned and carefully executed campaign with which other work is not allowed to interfere. Tillage operations should injure the quack grass as much as possible and should be repeated often enough to make effective the work that has preceded.

Eradication of quack grass on land that has been plowed each year is more difficult than on land that has been undisturbed for several years.

In carrying out the different rotations, a regular plan of "clean-up" to eradicate the quack grass was followed on each field with uniformly successful results. The plan was varied on three of the fields to secure additional data.

A four-year rotation on four fields, each one in turn having in successive years grain, hay, corn, and corn, gives exceptional opportunity for the eradication of quack grass. This rotation can be followed to advantage, especially on fields where quack grass is very vigorous or when weather conditions make the eradication unusually difficult.

The average cost per acre of the labor necessary for complete eradication, in addition to that which, under good farm practice, would be given the same fields growing identical crops, was as follows: Five-year rotation, $10.10; four-year rotation, $8.71; three-year rotation, $13.45; two-year rotation, $8.50; continuous-cropping schemes, $7.71.

MINNESOTA'S MOST SERIOUS WEED PEST

Quack grass is a more or less serious pest throughout the Northwest. In southern and central Minnesota this weed has established itself so thoroly that in some instances farms have been abandoned to it. In northern Minnesota it is already so widely distributed that time only is needed to make the occupation of waste places and poorly cultivated fields complete. The heavy black soil of the Red River Valley is ideal for the growth of quack grass, and the all-grain systems of farming, still too prevalent there, make prevention of spread difficult and eradication almost impossible after the weed is once well established. Every effort should be made to prevent its spread in the state and to keep it out of uninfested territory. In order to do this, it is necessary to know both the plant and its seed, for upon such knowledge methods of eradication are based.

Plant Characteristics

Quack grass is a perennial plant related to common wheat. Before heading out, it resembles *Bromus inermis*, a plant of considerable value both for hay and for pasture. The fact that *Bromus inermis* also spreads by underground stems makes the identification before heading-out all the more difficult. But close examination of the leaves and stems of the two plants reveals differences which make it comparatively easy to distinguish them.

Leaves of quack grass and *Bromus inermis* compared.—In quack grass the leaf sheath is open all the way down and the edges overlap (Figure 1, A). The leaf auricles, shown at B, are prominent, sharply triangular in shape, and clasp across the opening of the sheath. In *Bromus inermis* the leaf sheath is split only part of the way down, usually less than one-fourth or one-fifth of its total length (Figure 1, C), the lower part forming an unbroken ring around the stem. The auricles, shown at D, are not well developed.

Seed Characteristics

Quack grass seed ordinarily has a hull. Without the hull it is not recognized when mixed with other seeds. Seeds with hulls removed will grow. Therefore it is well to avoid seed grain containing them. When in doubt as to the identity of plants of weedy habits of growth and their seeds, residents of Minnesota should send a sample for examination to the Seed Laboratory, University Farm, St. Paul.

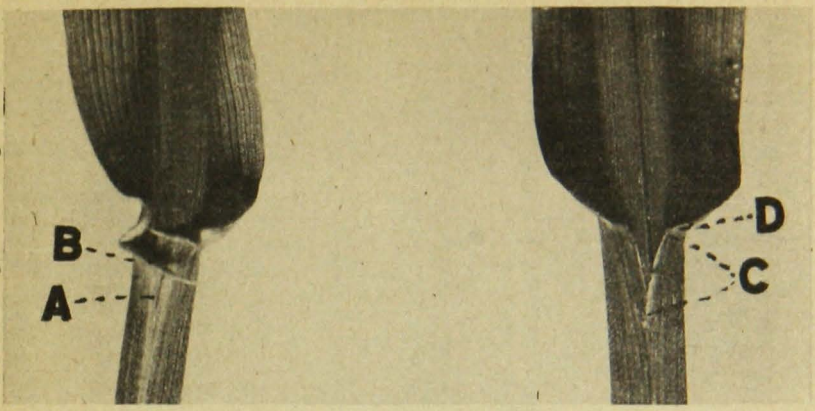

Fig. 1. Stems and Leaves of Quack Grass and *Bromus inermis*.
The overlapping edge of the sheath of quack grass is shown at A. The well-developed auricles are shown at B. In *Bromus inermis* the sheath is split only a short way, as shown at C. The lower and greater portion of the sheath is solid. The auricles, shown at D, are not well developed.

Immature Seed Will Grow

In order to ascertain at approximately what time quack grass must be cut in order that the seeds will be too immature to grow, seed was gathered at different times from July 6 to October 15, 1909, from patches that had been farmed differently in previous seasons. Duplicate samples were taken in some instances.

TABLE I. Stage of Development and Germination of Quack Grass Seed

Source of Seed	Notes	Date Gathered	Dates of Planting and No. of Seeds Planted			Percentage of Germination, 3-Year Average Field Test
		1909	1910 May 26	1911 May 31	1912 May 15	
Old sod	In blossom	July 6	100	100	100	
Old sod	In blossom	July 8	100	100	100	0.33
Corn field spring plowed	In blossom	July 9	200	200	200	.50
Old sod	In blossom	July 9	200	200	200	.66
Corn field spring plowed	Apparently in full bloom	July 12	200	200	200	.66
Old sod	Just out of blossom	July 12	200	200	200	3.83
Corn field spring plowed	In blossom	July 19	100	100	100	.33
Grain on corn ground	Seed in milk stage	July 19	100	100	100	13.00
Old sod	Seed in hard dough stage	July 19	200	200	200	31.33
Old sod	Seed in hard dough stage	July 20	100	100	100	34.33
Old sod	Seed in hard dough stage	July 22	200	200	200	29.96
Corn field spring plowed	Seed set	July 25	200	200	200	1.16
Old sod	Seed well filled	July 25	200	200	200	30.50
Corn field spring plowed	Seed in dough	July 30	200	200	200	2.50
Old sod	Seed well filled	July 30	100	100	100	24.66
Corn field spring plowed	Seed in dough	July 31	200	200	200	5.00
Old sod	Seed well filled	July 31	200	200	200	27.16
Old sod	Seed well filled	Aug. 10	100	100	100	23.00
Old sod	Seed well filled	Oct. 15	100	100	100	20.00

The tests show that quack grass seeds mature earlier on old sod where the vegetative growth is not strong on account of crowding than on cultivated ground, because there the mat of underground stems is broken up. They also show that the seeds will grow before they are mature.

TABLE II. Summary of Three-Year Germination Test

Source of Seed	Date Gathered	Number Tested	Average Percentage of Germination
Old sod..	July 9-31	1000	19 35
Corn ground, spring plowed	July 9-31	800	2 29
Difference in percentage of germination . .			17.06

Rye and barley usually mature about the middle of July. Samples of quack grass seed gathered July 19, the date rye was harvested in 1909, showed a high percentage of germination. Oats are harvested about August 1. The tests show viable seeds of quack grass gathered before and at about that date. Medium red clover and alfalfa are the only two crops commonly grown in the Northwest that are cut soon enough to destroy the quack grass seed before it is sufficiently mature to grow. Seed that mature in the field in July and August fall to the ground gradually. Some germinate in the autumn and the plants make considerable growth before winter. The rest do not germinate until the following spring.

Methods of Spreading

The seeds of quack grass are carried long distances in seed and feed grain, in baled hay, and in material used for packing purposes. Isolated spots of quack grass in uninfested territory can often be traced to one or the other of these sources. Inspection of baled upland hay shipped to University Farm reveals in practically every consignment quack grass seed that will grow. When grain or hay containing quack grass seeds is fed to animals, a varying proportion of the seeds pass through the digestive tract unharmed. The manure then becomes a carrier of the seed. Such manure should be used only where cultivated crops are to be grown. The seeds are also carried on farm machinery, and to a less extent by wind and running water. The plants spread mainly by underground stems. Parts of these may be carried from an infested spot by the plow or harrow and laid down where conditions for growth are good, and in this way a new center of infestation is formed.

Young Quack Grass Plants

In from two to four months from the time of germination (depending on conditions for growth) the underground stems begin to appear. For the first two or three months of its growth, a quack grass plant is just as easily killed as a wheat or oat plant of the same age. As the underground stems increase in number and length, the plants secure a firmer hold on the soil and eradication becomes difficult. This knowledge of the life history of the seedling is of value where it is necessary to use manure that contains quack grass seed. The best method of procedure in such cases is to apply the manure after the ground is plowed and disk it in preceding a corn or potato crop. In this way the seed are not buried deeply. The frequent cultivation, both in preparation of the seed bed and after the crop is up, furnishes ideal conditions for germination and growth and the next cultivation uproots and kills them. It is always good practice to go over the field with the hoe once or twice each season, to make sure that no quack grass is growing in the hills.

Underground Stems

Quack grass plants produce underground stems, by means of which they spread, and from any joint of which a new shoot may be sent up to develop into a plant. Where the ground is not disturbed, the underground stems are near the surface.

Fig. 2. Quack Grass Seedlings (May 27, 1910)

The plant in the center is just starting an underground stem, A. The hull of the seed is seen at B. The plant at the left is older and the underground stem, C, and the feeding-roots, D, are well developed. The plant at the right shows a still later stage of development. The stems of the seedling are shown at E. The underground stem, F, has produced a new plant, G.

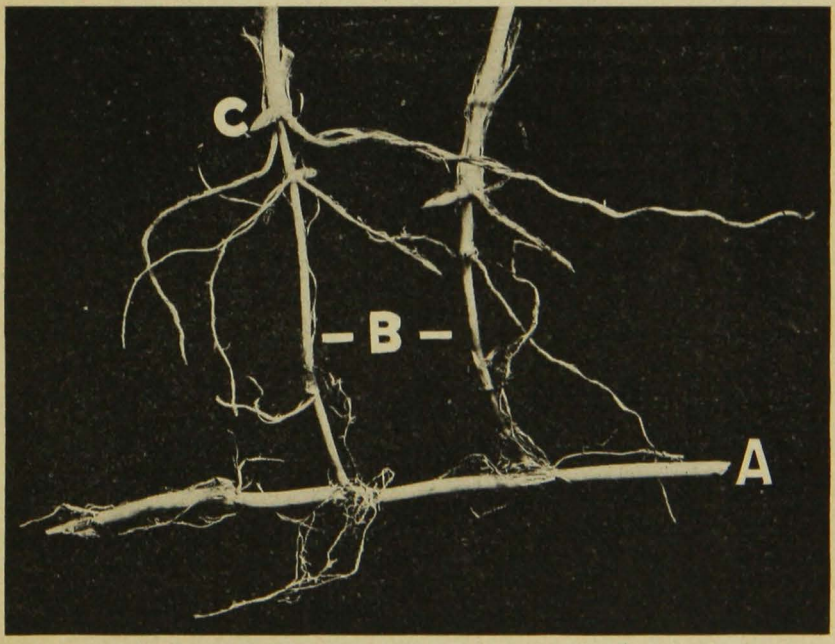

Fig. 3. Quack Grass Plant

A. An underground stem, two and a half inches below the surface.
B. Two branches which have produced stems and leaves.
C. New underground stems starting just below the surface of the soil. When these are well developed the old one will die.

In plowed fields they are distributed throughout the furrow slice and send shoots to the surface which in turn send out new underground stems.

On July 2, 1909, thirty vigorous underground stems were secured and cut to lengths of five joints (nodes) each. Thirty pots, six inches or more in diameter, were filled with soil and one of the underground stems planted in each one inch below the surface. These pots were sunk in groups of five each so that the underground stems were respectively 2, 4, 6, 8, 10, and 12 inches below the surface of the soil. On July 16, the underground stems buried to a depth of 2 inches had sent to the surface 14 stems and those buried 4 inches had sent up 3 stems. On July 22, those buried to a depth of 2 inches had sent up a total of 21 stems and those buried 4 inches a total of 4 stems. The underground stems buried to a depth of from 6 to 12 inches had sent up stems varying from 3 to 4 inches in length but none of them reached the surface. On August 2, the plants from the underground stems buried to a depth of from 2 to 4 inches had broad leaves and were making rapid growth. Those buried 6 to 12 inches deep produced weak shoots from 4½ to 5½ inches long, and had apparently reached the limit of their growth before they reached the surface but were not yet dead.

This indicates that in plowing from 6 to 8 inches deep some underground stems are buried so deep that they are unable to send new shoots to the surface. However, no matter how carefully or how deep ordinary plowing may be done, there are always numerous underground stems within 4 or 5 inches of the surface.

Condition of underground stems in summer and in autumn.—In order to determine the weight and composition of the underground stems of quack grass, six square yards of thoroly and evenly infested soil were laid off. Those in three square yards were dug June 28, 1909, washed, and weighed, and a sample was submitted to the Division of Agricultural Chemistry and Soils for analysis. On November 10 those in the other three square yards were dug and weighed, and a sample was submitted for analysis.

The average weight per square yard on November 10 was 3.43 times that on June 28. On June 28 the approximate green weight of the underground stems per acre was 2.42 tons; on November 10, 8.3 tons. The percentage of nitrogen was considerably higher in November than in June. The percentage of phosphoric acid was the same in both samples. The percentage of potash and lime varied, probably on account of the difficulty in washing off all the soil. This supports the idea that the best time to start eradication of quack grass is in June or July. The underground stems weighed less and were lower in percentage of both dry matter and nitrogen in June than in November. An increase in weight from June to November would be expected in all cases except possibly in fields that had been abandoned to quack grass for a long time and had become very much sodbound.

Eradication of Small Patches

Where quack grass is found growing in patches a square rod or less in size, it is highly desirable to follow a method of eradication which allows the working of each infested spot separately. Such a method confines the underground stems to the infested areas and reduces to the minimum the danger of spreading by means of tillage implements. Several methods of eradicating quack grass in small spots have been tried, and, with care, some have proved entirely successful.

Hemp was planted thickly and grew to a height of from 6 to 10 feet. The quack grass was hurt but still showed. A repetition of the treatment for several seasons would probably choke out the quack grass.

One of the objections to the use of hemp as a smother crop is that there is little use on the farm for the crop after it is grown. Substituting silage corn for hemp

allows cultivation of the soil preceding the planting and while the crop is growing. The use of buckwheat instead of hemp gives six weeks longer in which to work the soil before the crop is planted.

Kerosene was applied at the rate of 80 gallons per acre at heading time. "The plants looked sickly for a few days but soon recovered."

Salt was applied, both dry and in the form of brine at the rate of 80 barrels per acre. "The tops were killed but the roots soon sent up new plants as vigorous as ever."

Sulphuric acid was found to be effective when 40 or 50 gallons of a 15-per-cent solution were applied per square rod. "This would cost about $5 per square rod, thus making the use of acid impracticable."

Tar paper was spread over a square rod of quack grass on July 7. "Two days later the tops were all dead above ground and a month later the roots were apparently completely dead. The cost of the tar paper would be from 75 cents to $1 per square rod. . . . . This method may be practicable for small patches."

Digging by hand "is probably as good a method as any, where there are but a few small patches. Great care should be taken to get all roots out and off the ground."

Gasoline was applied September 3 at the rate of 1 gallon per square rod. The leaves turned black but the plants quickly recovered. In April following no effect could be noted.

White arsenic was dissolved at the rate of 4 pounds in 10 gallons of water in which 8 pounds of salsoda had previously been dissolved, and this amount applied per square rod. The white arsenic did not dissolve readily except when the water was heated. The leaves turned black and some of them were killed, but no effect could be noted two months later.

Sodium arsenite was applied on August 29, 1914, at the rate of 4 pounds, dissolved in 10 gallons of water, per square rod. Ninety per cent of the plants were killed. The rest were weakened but were growing when examined at intervals up to November 9. The application of 8 pounds of sodium arsenite dissolved in 20 gallons of water, to the square rod, should ordinarily kill all the plants. At 12 cents per pound for sodium arsenite, the cost would be approximately $1 per square rod, exclusive of the expense of applying. The high cost makes the use of this chemical practicable on small areas only. It can be used to advantage on small patches in rough places where covering with tar paper or digging by hand would be difficult. Sodium arsenite applied in sufficient quantity to kill the underground stems makes the land sterile for some time but not permanently so.

Sodium arsenite is a deadly poison and should never be used in pastures or on grass in unenclosed fields where stock may gain access to it.

Commercial spray was applied at the rate of from 1 to 6 barrels per acre, with slight immediate change in the appearance of the plants and no permanent effect. The price was $6 per barrel. All commercial sprays advertised to eradicate quack grass should be fully investigated and carefully tried out under controlled conditions before much money is invested.

Eradication on Badly Infested Fields

The lack of definite data regarding methods of eradicating quack grass successfully where it is distributed over entire fields made it desirable to try several ways. All successful methods of eradicating quack grass from large areas are based on thoro tillage. Tillage operations may be: (1) to drag the underground stems to the surface where they are killed by exposure to wind and sun; or (2) to turn the

plants under completely, and by shallow tillage keep the new shoots from showing green above ground, in this way starving the plants out; or (3) a combination of these two methods.

Tillage Operations and Implements.—Special machinery means extra expense and would in many instances cause the owner of an infested field to hesitate before beginning operations. Therefore in the field experiments reported in this bulletin only those implements were used that are ordinarily found on any well-equipped farm.

Fig. 4. Well-plowed and Poorly Plowed Fields

The plow used on the field at the left was equipped with a jointer. All parts of the plants were turned under and the growth was seriously interrupted. No jointer was used on the field at the right. Many of the plants were not covered and continued to grow.

Plowing is the fundamental tillage operation. It if is well done the other operations will be effective.

A plow equipped with a properly adjusted jointer makes it possible to turn under all of the green parts of the quack grass and many plants die from lack of

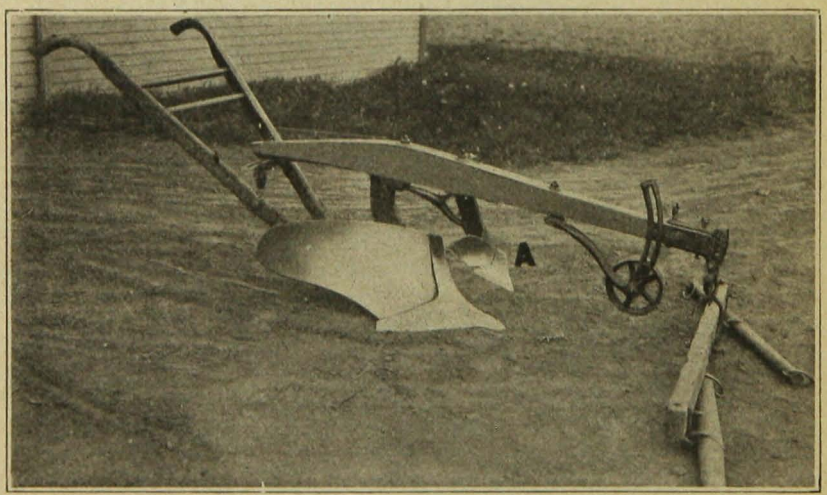

Fig. 5. Plow with Jointer

With a plow equipped in this manner stems and leaves in a tough sod can be covered completely. The jointer is shown at A.

air. The underground stems immediately begin to send up new stems and leaves, but for a time the growth of the plant is decidedly checked. Poor plowing leaves some of the green parts of many plants exposed and growth is continued without interruption.

After the experiments were well under way it was found that eradication of the quack grass was more difficult on the back furrows than anywhere else in the field. In striking out a field by the method ordinarily followed, approximately 18 or 20 inches of sod is left unturned. If, instead of throwing the second furrow slice over against and overlapping the first, as is usually done in making a back furrow, the second is cut immediately under the one turned over in striking out the land and both are turned back toward the first furrow, this difficulty is largely overcome. It is important that all of the land be cut and turned in the operation of plowing.

Harrowing is valuable in the preparation of the seed bed. Where occasional spots of quack grass occur in a field it is best to work these separately, so that underground stems are not dragged to the uninfested parts. The plots and fields used in the experiments here reported were thoroly infested so that further spreading was not considered. In the experiments, however, the harrow was used only in the preparation of the seed bed and in the first cultivation of the potato and corn crops, except on Plots 5 and 6 of the McCausland field, where it was used throughout the season to drag the underground stems out of the ground.

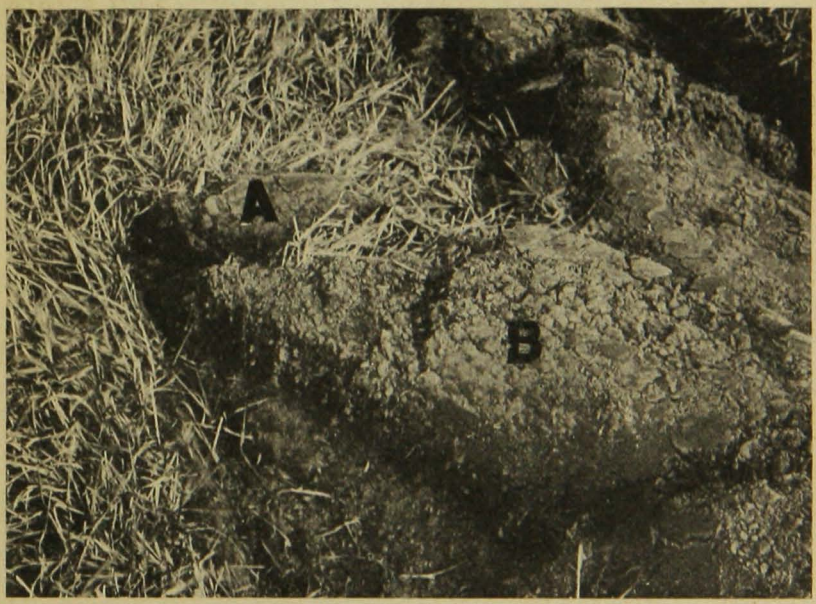

Fig. 6. Work of the Jointer

The thin ribbon stripped off the upper edge of the furrow slice is shown at A; the furrow slice, at B. When the field is carefully plowed no quack grass will show at the edge of the furrow slice.

Double disking each plot or field as soon after plowing as possible was done in order to pack the ground and form a dust mulch to exclude the air so that the green leaves and the stems would be killed more quickly. Further double diskings were given as needed to keep the new stems from showing green above ground.

Light rainfall facilitates weed eradication.—Light rainfall during the growing season facilitates weed eradication. With less than the normal amount of

moisture in the soil the plants are not so vigorous as they would be under more favorable conditions, and those on the surface die more readily.

On heavy soils such as that on the McCausland field, copious and frequent rains make cultivation difficult, and the operations are too far apart to be effective. On the lighter kinds of soil, such as that on the Hannaford field, cultivation can proceed except immediately following the heaviest rainfall.

THE McCAUSLAND FIELD EXPERIMENTS

In the spring of 1909 a series of experiments in the eradication of quack grass was planned, (1) to try out methods of summer fallow followed by a cultivated crop, and (2) to compare the efficiency of millet and buckwheat as smother crops when not preceded by thoro tillage. The tract of land secured for the experiments had been cropped by renters for several years. In 1908 corn was raised on it and was not well cultivated. Only the part most densely covered with quack grass was selected for the experiments. It was level and lay slightly lower than the rest of the tract. The underground stems of the quack grass were very vigorous and well distributed throughout the soil to a depth of from 3 to 5 inches. The soil was a heavy black loam with a clay subsoil.

The Plan

Plot No. 1. Plowed 8 inches deep July 1. Double disked as soon as plowed and as often as necessary to keep the quack grass from showing green above ground throughout the summer and fall until the ground was frozen. Disking begun early the following spring and continued as needed to corn-planting time.

Plot No. 2. Procedure same as on Plot 1 except that the plot was replowed late in the fall.

Plot No. 3. Plowed 3 or 4 inches deep July 1. Double disked as soon as plowed and as often as was necessary to keep the quack grass from showing green above ground until August 15. Replowed August 15, 5 inches deep. Double disked as needed until the ground was frozen. Disking begun early the following spring and continued as needed to corn-planting time.

Plot No. 4. Procedure same as on Plot 3 except that the plot was replowed late in the fall.

Plot No. 5. Plowed 3 or 4 inches deep July 1. Harrowed the same day and as often as necessary thereafter.

Plot No. 6. Plowed 7 inches deep July 1. Double disked and harrowed as soon as plowed and as needed throughout the summer and fall. Replowed 8 inches deep late in fall. Double disking and harrowing continued in early spring and up to corn-planting time.

Plot No. 7. Plowed 8 inches deep July 1. Double disked and harrowed as soon as plowed. Hungarian millet sown as a smother crop at the rate of 1 bushel per acre. Millet plowed under in September and double disking and harrowing continued.

Plot No. 8. Procedure same as on Plot 7 except that buckwheat was sown at the rate of 2 bushels per acre as the smother crop.

Summary of the McCausland Field Experiments

Shallow plowing in July followed by double disking as needed until the middle of August and then replowing somewhat deeper than before with the disking continued until the ground was frozen, proved more effective in the eradication of the quack grass than deep plowing in July followed by disking only for the same length of time.

The use of the harrow following each double disking was found to aid materially in the eradication of the quack grass. It levels the ground and exposes completely portions of the underground stems which are near the surface but still covered enough to live.

Replowing late in the fall helped in the eradication, not so much by exposing the underground stems to the action of the frost as by turning the living portions under. This checked growth during late fall and early spring.

Shallow plowing during July followed by frequent harrowings was not effective in eradicating the quack grass.

Buckwheat and millet sown during the first part of July on newly plowed quack grass sod were not effective in holding the quack grass in check during the period they occupied the ground.

THE HANNAFORD FIELD EXPERIMENTS

In order to try out methods of quack grass eradication on larger fields under farm conditions, plans were outlined early in the summer of 1909, and a forty-acre tract, approximately half a mile south of the town of Monticello, Wright County, was rented for a period of five years beginning October 1, 1909. This location was chosen because a field of the desired size thoroly infested with quack grass was available and so located that the progress of the work could be seen from two main roads. The tract was so uniform that yields from the different fields were comparable.

The Soil

The soil is a black sandy loam. Water stands in three places on the surface for a few days in spring and after heavy rains. With these exceptions the drainage is good.

History

The field was without buildings and had been rented for several years. The north part, comprising from 8 to 10 acres, had been in meadow. Close examination at the beginning of the experiment showed it to be well covered with quack grass in a sod-bound condition. As nearly as could be learned the crops on the south portion had been as follows: 1904, rye; 1905, corn; 1906, buckwheat; 1907, flax; 1908, buckwheat; 1909, hay. The yields had been very unsatisfactory. The quack grass on the south part was not so badly sod-bound and the underground stems were deeper on account of the plowings. A strip through Fields G and H, and B and C was plowed in July, 1909, when the owner intended to start summer fallow. No further work was put on it. It had been cultivated enough to break up the sod-bound condition of the quack grass, which allowed it to grow with new vigor. At the time it was rented, the forty-acre tract was valued at $30 per acre and other fields near it, of the same quality but not so badly infested, at from $40 to $50 per acre or more.

Manure applied on plowed ground preceding a cultivated crop.—The only livestock kept was a team of horses. The only way to get manure was to haul it from town and all of it was known to contain more or less quack grass seed. Therefore the manure was applied on the plowed ground and disked in at the time the seed bed was being prepared for a cultivated crop. The knowledge of the habits of growth of the seedlings of quack grass made this a safe method of procedure.

A "clean up" time needed in each rotation.—Following out a rotation on a field or several fields, does not necessarily mean that the weeds growing there will be eradicated. As carried out in actual practice, the indifferent tillage given crops in rotations often allows the quack grass to spread rapidly and gain a firmer

hold. However, it appeared reasonable to suppose that if rotations were planned to provide for thoro tillage and more than the ordinary number of cultivations were given, the quack grass could be completely eradicated without losing a crop in any instance. Therefore at a certain time in each rotation a clean-up was planned, so thoro in its nature that the quack grass was either killed out completely or so weakened that it could not make much headway before the next clean-up time.

General plan of clean-up followed.—Hay and rye were included in the rotations because these crops are usually removed early in July. The ground was plowed as soon as practicable after the removal of these crops and double disked in the direction in which the furrows were turned. Following this the field was double disked as often as necessary to keep the quack grass from showing green above ground throughout the summer and fall, until the ground was frozen.

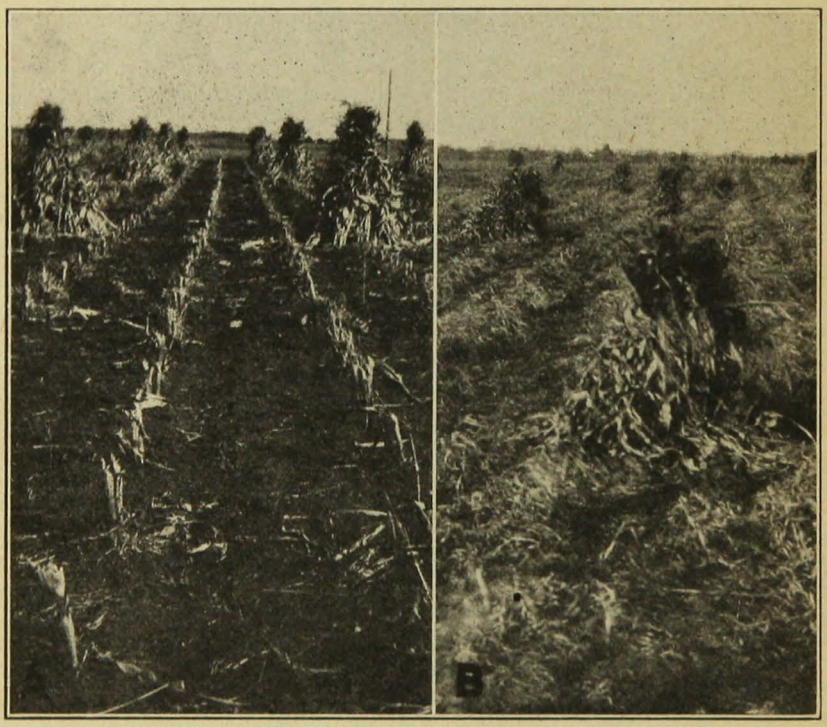

Fig. 7. A Contrast

A. One of the corn fields at the end of a clean-up time. The general plan of clean-up was followed. Very little hand work was needed.

B. A field on an adjoining farm where quack grass was originally no worse than on the field shown at A. No work was done on this field the previous season to kill out the quack grass and the corn was not cultivated thoroly.

If at any time the disk was not able to cut off or uproot the quack grass, the field was plowed and the disking continued. At no time was the field left long enough without cultivation for the quack grass to start. This is very important, because without green leaves to build up food material the quack grass can not live. Quack grass many times gains a new hold because of its ability to grow late in fall and very early in spring. The fields were double disked late in the fall and early in the spring and as needed until corn- or potato-planting time. Then the culti-

vated crop was planted and kept clean. Hand work was used when needed to remove quack grass from the hills. Starting the work of eradication as soon as the first hay crop or an early-maturing grain crop is removed, gives approximately five months of bare fallow without losing the use of the land for the year. The cultivation of the corn or potatoes following the thoro tillage which precedes the planting of these crops, makes it possible to kill the few plants that may be left. This same clean-up method was followed on the millet, buckwheat, and fodder-corn fields but the work was begun early in spring and continued on the fields planted to millet and buckwheat up to about July 1. This gave the three spring months for bare fallow preceding the planting of the crop. As soon as the buckwheat and millet were removed, the fields were plowed and disked frequently until the ground was frozen.

The clean-up plan included thoro eradication of all quack grass along roadsides and fence rows. Precautions were taken to prevent reinfestation through quack grass seed distributed in the manure, by early frequent cultivation following the application of manure.

Labor Records and Cost of Eradication

A complete record of operations and the time required for each was kept for every field throughout the five years. A record was also kept of all other costs on each field. This includes: (1) The rent paid per acre, as follows: 1910, 49 cents; 1911, 54 cents; 1912, $1.08; 1913, $1.62; 1914, $1.62; (2) the machinery cost per acre; (3) the cost of seed and binding twine, and of threshing. The labor cost of applying manure is charged to each field. For the years during which no additional effort was made to eradicate the quack grass, the operations were the usual ones in handling the crops and the complete record is not included in this bulletin.

Labor Cost of Eradication

Labor comprises the largest item of expense in the complete eradication of quack grass on large fields. The tillage given crops under good farm practice necessarily varies considerably with the condition of the soil and the season. One double disking in preparation of the seed bed for grain or a cultivated crop, and four cultivations of the corn and potato crops is about the average. It is important that small grains be sown in a well-prepared seed bed at the proper time. If the harrow is not effective the disk may be used. A small area well planted is usually more profitable than more ground poorly planted. In order to compare the labor cost of eradicating quack grass in the different rotations and cropping schemes followed, the amount of work in addition to that ordinarily needed to care for the crops under good farm conditions is expressed in terms of cash. The labor cost of all the operations on each field is computed at 13½ cents per hour for man labor and 9¼ cents for horse labor.

Facts to be Considered in the Interpretation of the Results of the Hannaford Field Experiments

Drouths are of rare occurrence in Minnesota and usually local in effect. A drouth occurred in 1910 at Monticello and caused a complete failure of crops on all the fields included under the experiment except those on which corn was planted. The corn did not make a normal growth and was used for fodder only. The almost complete crop failure of 1910 reduced the five-year average receipts per acre. While the receipts from the different fields are not always equal to the expenditures, the five-year average is nearly so. It should be noted also that all labor cost and other expense is deducted from the receipts. Therefore under like conditions for the eradication of quack grass the farmer would be receiving a labor income. Under the circumstances, the fact that the receipts nearly equaled or slightly exceeded the expenditures, including the labor cost, is very encouraging.

The Five-Year Rotation

A five-year rotation consisting of grain, hay, hay or pasture, corn, and grain, carried out on five fields of approximately the same size, is well adapted for use on many stock farms in the Northwest. This arrangement gives each year two-fifths of the farm to grain, two-fifths to hay or pasture, and one-fifth to corn, and supplies approximately the amount of feed needed, besides grain and possibly some hay for market.

Summary for the five-year rotation.—On the fields where the five-year rotation was carried out regularly or nearly so and the outlined preliminary work preceded the cultivated crop, the quack grass was completely eradicated.

The five-year average cost of the labor above what would be put on the same fields growing identical crops under good conditions, was $10.10 per acre.

The Four-Year Rotation

On many stock farms a five-year rotation as carried out on Fields A to E inclusive, would not give a sufficiently large acreage of corn each year. A four-year rotation consisting of grain, hay, corn, and corn, carried out on four fields of approximately equal sizes, gives one-half instead of one-fifth of the acreage to corn each year. Part of the corn may be planted for silage and part for grain. For weed-eradication it was thought the four-year rotation would prove superior to the five-year, since the clean-up time would come more often and could be made more thoro with two cultivated crops in succession to complete the eradication work, which should be started as soon as the hay crop is removed.

Summary for the four-year rotation.—On each of the fields in the four-year rotation, eradication was completed readily during the clean-up time outlined for the work, at a comparatively low cost per acre. The five-year average cost of the additional labor necessary for complete eradication was $8.71 per acre.

The Three-Year Rotation

A three-year rotation consisting of grain, clover hay, and a cultivated crop is adapted for use on many farms where considerable attention is given to potato-raising. While the three-year rotation does not offer greater opportunities for weed eradication than does the five-year, the opportunity comes more often and therefore may be more effective.

Summary for the three-year rotation.—The first clean-up on Field F was started in July, 1912, and finished in 1913, with complete eradication of the quack grass as the result. Therefore it was not necessary to make use of the opportunity for the second clean-up which presented itself in July, 1914, at the time the first hay crop was removed. The cropping on Fields G and H was not regular. The frequency of the opportunity for eradication commends this rotation.

The five-year average cost of the additional labor needed for complete eradication of the quack grass on all of the fields in the three-year rotation was $13.45 per acre. The labor cost of $7.63 per acre on Field F represents more nearly what the cost would have been had the regular order of clean-up been followed out on all three fields.

Two-Year Rotations

Two short rotations were planned, winter rye followed by corn, and winter rye followed by early potatoes. It was thought these would be suitable for small fields and in some instances for larger fields where it is desired to do work toward eradicating quack grass more often than can be done while following out a longer rotation.

The winter rye-corn rotation was carried out on Fields I and J. The winter rye was sown with a drill in the standing corn about September 1. The winter rye-early potato rotation was carried out on Fields K and L. The potatoes usually were off the ground by the latter part of August. The tops were then raked off and the ground disked in preparing the seed bed for the rye. Manure was applied preceding the corn and potato crops. The rotations were carried out without any changes.

Summary for the two-year rotations.—Both of the two-year rotations give ample opportunity for complete eradication of the quack grass in two years' time. The fact that the opportunity for eradication comes every other year, commends these two rotations for use.

The five-year average of the additional labor needed for complete eradication of the quack grass on the fields in the two-year rotations, was $8.50 per acre.

The Continuous-Cropping Schemes

Five continuous-cropping schemes were outlined using quick, dense-growing crops that give opportunity for fallow in late autumn and in early spring before planting-time. It was thought that these methods could be used on small fields where it is desired to grow a crop each year and yet eradicate the quack grass as quickly as possible.

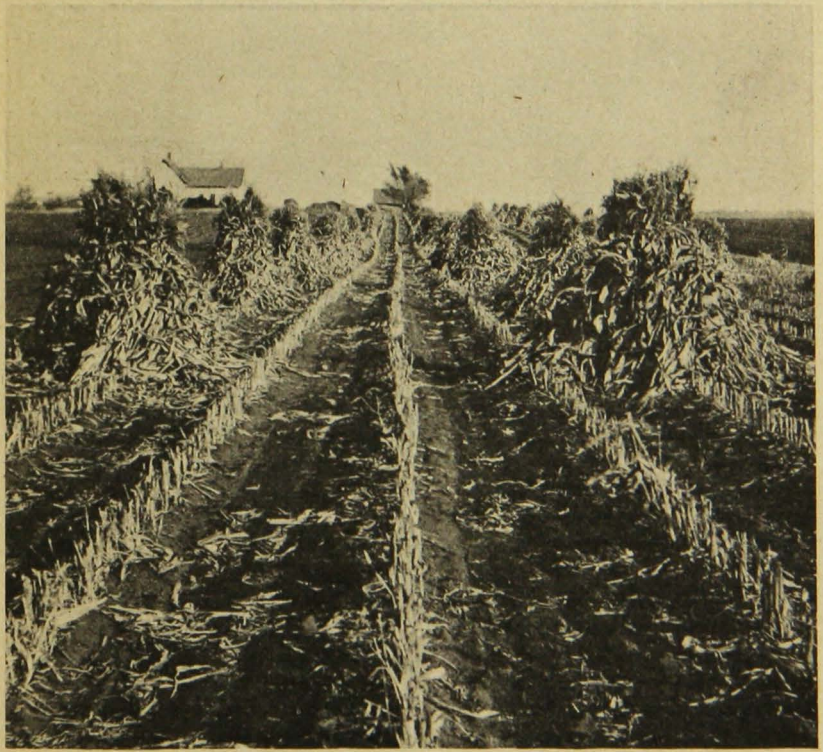

Fig. 8. Field M, Fodder Corn Each Year, Kept Thoroly Clean

After three years of this treatment the field was free from quack grass. A good crop of fodder corn was secured each year.

Fodder corn was grown continuously on Field M. The field was plowed as soon as the corn was removed in the fall and disked thoroly in preparation for the corn in the spring. The corn was planted at the rate of 35 pounds per acre. Fields O and P were fall plowed, disked, and replowed in the spring. Fields Q, R and M were fall plowed only. Buckwheat was sown on Fields O and R at the rate of 2 bushels per acre, anp millet on Fields P and Q at the rate of 1 bushel per acre.

Clean-up time in the continuous-cropping schemes.—In each instance the field was plowed as soon in autumn as possible. The disking was begun early in spring and continued up to planting-time.

Summary for the continuous-cropping schemes.—The quack grass was completely eradicated in three years or less on each of the fields cropped continuously to fodder corn, buckwheat, or millet at a five-year average cost for additional labor of $7.71 per acre.

On farms where considerable silage is fed, growing corn on infested land for three or four years in succession and giving it careful cultivation is one of the best and cheapest methods of eradicating quack grass without losing a crop. Sufficient manure must be applied to keep up the productivity of the soil under this system.

As silage corn is removed from the field early in September, better opportunity is given for the eradication of the quack grass than when fodder corn is grown. The field may be plowed early in September and the disk or spring-tooth harrow used until the ground freezes in the fall and again early in the spring and up to corn-planting time. This gives practically three months of fallow between corn crops.

The buckwheat and millet crops are not important on farms in the Northwest. In weed-eradication buckwheat is superior to millet. It grows more rapidly at the start and covers the ground more completely at all stages of growth. It produces, on the average, good yields of grain which when ground may be profitably fed to hogs, or unground, to poultry.

Results Obtained in the Rotations and Cropping Schemes on the Hannaford Field

1. In any of the rotations followed the quack grass was completely eradicated in all cases where the field was carefully tilled from the beginning of August to the time the ground was frozen and again the next spring to corn- or potato-planting time. The corn or potato crop was kept clean.

2. While the eradication was complete on all the fields in any of the rotations where the regular clean-up plan was followed out, the four-year rotation gave an exceptionally favorable opportunity to combat weeds. Careful tillage from the first of August to the time the ground was frozen, followed by corn crops two years in succession, allowed intensive cultivation for a longer period than in the other rotations. On fields where the quack grass is vigorous or during unusually wet seasons, the two successive years to a cultivated crop are needed to make certain that the eradication is complete.

3. With the exception of the four-year rotation, the opportunity for the eradication of quack grass was the same in all rotations. The shorter rotations, however, gave the opportunity for a thoro clean-up more often.

4. Planting fodder corn three years in succession and keeping it well cultivated proved a very efficient and economical method of eradicating quack grass. Each year the field was carefully cultivated from early spring to corn-planting time.

5. Growing buckwheat for three successive years on fall plowed land cultivated from early spring to July 1 resulted in complete eradication of the quack grass.